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The impact of intangible assets on the productivity of manufacturing firms in Turkey

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Abstract

As the experiences of industrialized economies have shown, "intangible capital" such as R&D expenses, patents, copyrights, franchises or licenses, and trademarks, represents a key component of the knowledge of firms that are crucial to their performance. The aim of this paper is to investigate the impact of capital inputs on productivity in Turkish manufacturing industry. Using firm-level data from 2003 to 2012, we compare the impact of tangibles and intangibles, as well as different types of intangibles on productivity. Our findings based on the estimation of a Cobb-Douglas production function by using Generalized Methods of Moments (GMM) and a semi-parametric estimation method proposed by Olley and Pakes (1996) show that firms with increasing level of expenditure for intangible assets experienced an increase in their productivity. In addition, the effect of intangible assets on productivity is especially significant for computer software and patent capital.

Key words: Productivity, tangible and intangible assets, manufacturing industry, Turkey.

JEL codes: D24, L60, O14.

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1. Introduction

We all know that the sole source of long run economic growth is productivity increase. This is evident from the stylized fact that the twentieth century has witnessed remarkable productive increases not only in manufacturing but also in the other industries. The contribution of factor accumulation, especially capital, in this productivity increase was quite significant at least until the 1970s. Productivity increase in most of the developed world, however, has slowed down in the 1970s and 1980s (Solow, 1987; Draca et al., 2006; Hulten, 2001).

A new era of productivity increase in both manufacturing and other industries started in the 1990s. Productivity increase in this second period was mostly attributed to the widespread use of a specific form of tangible assets, information and communication technologies (ICT). Today, there are many studies conducted at the country, sector or firm/plant level estimating productivity and quantifying the impact of ICT on productivity growth (for a detailed survey, see Biagi, 2013). However, we still know little about the effects of different types of intangible assets (R&D expenses, patents, copyrights, franchises or licenses, trademarks or trade names, and goodwill) on productivity.

One important change that has taken place in evaluating the impact of factor accumulation on productivity growth is the acknowledgement that knowledge capital is more than R&D: it also includes other expenses for intangible capital such as design and licenses, computerized information, brand equity, firm-specific human capital, and organizational capital. The other important change in this research strand is the improvement of the measurement of intangible assets that was a challenging task due to data limitations. Data for some of these components, like scientific R&D, are well documented, internationally harmonized and comparable to a large extent. Other categories like organizational capital, however, are rather roughly measured so far. Moreover, accounting rules for these components differ across accounting standards such that some parts of these components have to be capitalized if they fulfill certain criteria, others are not allowed to be capitalized and are treated as expenses (Crass and Peters, 2013: 2).

At the macro level, Corrado et al. (2009) provide a consistent framework for the measurement of intangible assets and confirm the importance of intangible goods for economic growth. They find that the inclusion of intangibles makes a significant difference in the measured pattern of economic growth: the growth rates of output and output per worker are found to increase at a noticeably more rapid rate when intangibles are included than under the baseline case in which intangible capital is completely ignored (Corrado et al., 2009: 663). Using a growth accounting framework, Corrado et al. (2009) show that intangible investment stimulates labor productivity growth in the United States by 0.84 percentage points. The growth enhancing effect is smaller in many European countries but still considerable: Labor productivity was boosted by 0.58 percentage points in the UK (Marrano and Haskel, 2007), and by 0.53 in Germany (Crass et al., 2010).

Notably, these findings stress the importance of intangible assets for (labor) productivity in general. The studies mentioned above have analyzed the effect of intangible assets at the country or highly aggregated industry level. It is common knowledge, however, that there is an extremely large heterogeneity in productivity at the firm level, even within the same industry. Therefore, with the improvements in the measurement of intangible assets, there are recent contributions to the literature confirming the importance of including intangible assets as determinants of firm's productivity.

In a recent study, Marrocu et al. (2011) examine the impact of (capitalized) intangible capital on firms' productivity level in six European countries: France, Italy, Netherlands, Spain, Sweden and the United Kingdom for the period 2002 to 2006. Based on a Cobb-Douglas production function approach estimated by the semi-parametric estimation method proposed by Olley and Pakes (1996) and Levinsohn and Petrin (2003), they confirm a highly significant effect of intangible capital on productivity. Even if the estimated elasticity of capital is about 0.04-0.06 that is only roughly half as large as that of physical capital for the production function estimates, the growth rate of labor productivity estimates reveals that the impact of intangible capital turns out to be higher than that of physical capital (Marrocu et al., 2011: 388).

Crass and Peters (2013), following the conceptual framework of Corrado et al. (2009), explores to which extent different kinds of intangible assets are conducive to firm level productivity. Their study contributes to the literature by simultaneously comparing productivity effects of innovative capital (measured by R&D expenses, patent stock and design & license expenditure), human capital (proxied by training expenditure and share of high skilled labor), branding capital (measured by marketing expenditure and trademark stocks) and organizational capital (proxied by the introduction of an organizational innovation). Moreover, they test whether complementarity or substitutability exists between different intangible assets. Using panel data for German companies for the period 2006-2010, they confirm strong positive productivity effects of R&D capital, branding capital (trademarks)[1] and firm-specific human capital whereas the different types of organizational innovations seem to have no significant impact on labor productivity (Crass and Peters, 2013: 15).

The study by Bontempi and Mairesse (2015) goes beyond the impact of purely capitalized intangible assets. They compare the productivity effects of intangible

1 For another study evaluating the role of patent and trademark registrations on productivity, see Greenhalgh and Rogers (2012).

relative to tangible capital by differentiating between capitalized versus expensed intangible capital on the one hand and intellectual (mainly R&D and patents) versus customer intangible capital (mainly advertising, trademarks) on the other hand. Using data for Italian firms, their estimates also provide evidence that intangible capital has a stimulating effect on productivity levels (estimated output elasticity of about 0.03–0.07 range) (Bontempi and Mairesse, 2015:45). Moreover, the highest marginal productivity is that of intellectual capital, customer capital and intangible assets showing that intangible capital and its different components are at least as productive as tangible capital.

The most prominent components that have deserved a lot of attention in the literature are R&D and computerized information. There is a substantial literature studying productivity effect of R&D (for recent survey, see Hall et al. 2010). Starting with the seminal work by Griliches (1979), many studies have investigated the impact of R&D on productivity at the firm level. Hall et al. (2010) conclude that most studies show a significant positive private return to R&D, ranging mostly between 20 to 30%. The corresponding output elasticity of R&D ranges from 0.01 to 0.25 in most studies but it often centered on 0.08 (Hall et al., 2010:1055).

An increasing number of studies have investigated the effect of information and communications technologies (ICT) on productivity. These studies provide empirical evidence of a positive and significant relationship between ICT investment and firm productivity (for a detailed survey, see Brynjolfsson and Hitt, 2003; Hempell, 2005 or Draca et al., 2006). Using firm level data to study the relationship between ICT and firm performance, empirical studies adopted different methodologies. The first methodology is the inclusion of ICT capital stock at firm level as a separately identified capital input in total factor productivity (TFP) analysis (Brynjolfsson and Hitt, 2003 and Hempell, 2002). Another methodology is the inclusion of ICT capital alongside other measures of ICT use, such as Internet use or number of employees using ICT (Maliranta and Rouvinen, 2003). The third one is to include ICT capital stock with measures on innovation and/or organizational change (Van der Wiel and Van Leeuwen, 2003). The last methodology is the inclusion of measures of computer network use (i.e. behavior) as an additional determinant of TFP in a productivity regression equation (Atrostic and Nguyen, 2002).

A recent and extensive work by Van Reenen et al. (2010) evaluating the impact of ICT on productivity uses a panel of European firms drawn from the AMATECH database. This database includes approximately 19,000 firms across 13 countries covering the period 1998-2008. They use a measure of ICT capital that is constructed as the number of laptops and PCs per worker that is effectively a hardware-only measure of ICT capital. Using GMM-System method, they find that a 10% increase in ICT capital is associated with a 0.9% increase in output. More pointedly, it is higher than the share of ICT capital in output (which is approximately 1-2% for this sample) and therefore suggests very high returns to ICT capital.

There exist a number of studies that calculate TFP growth for the Turkish economy for the post 1960s period and examine its evolution on the aggregate economy and on sectoral basis – see for example, Saygılı et al. (2001, 2005), Altuğ and Filiztekin (2006), Altuğ et al. (2008) or Ismihan and Metin-Özcan (2008). Regarding the manufacturing sector in Turkey, there have been a considerable number of studies dealing with productivity (see for example, Krueger and Tuncer, 1982; Yıldırım, 1989; Aydoğuş, 1993; Gökçekuş, 1997; Önder and Lenger, 2003; Zaim and Taşkın, 1997). There are studies that measure changes in TFP and also changes in its components (technical efficiency) in the Turkish manufacturing industry for different regions as well as for different ownership structures; namely public and private. These studies also differ in their methods of computing productivity (for studies using *stochastic production frontier models* see, Taymaz and Saatçi, (1997) and Önder et al. (2003a); for studies using *Malmquist productivity indices* see, Karadağ, et al. (2005) and for studies using *data envelopment analysis (DEA) method* see, Önder et al. (2003b)).

Empirical studies regarding productivity analysis in Turkey use longitudinal data at the plant level mostly in order to investigate productivity changes during increased trade openness and participation in international activities. Taymaz and Yılmaz (2007) and Özler and Yılmaz (2009) are two studies that analyze the productivity response to trade policy changes for Turkish manufacturing plants spanning the period of 1984-2000, following the procedure of Olley and Pakes (1996). They observe that productivity gains are largest in import competing industries, compared to export-oriented and non-traded sectors. In a recent study, Taymaz et al. (2009) evaluate the plant-level total factor productivity in the manufacturing industry from 1984 to 1996. They show that after 1988, TFP followed an upward trend until 1993, with an average growth rate of 5% per annum, before it got completely stalled after the 1994 economic crisis.

Even though there is a substantial literature evaluating the impact of factor accumulation on productivity growth, less is known, however, about productivity effects of other types of intangible assets. To the best of our knowledge, although there are few studies that examine the impact of ICT on productivity growth in Turkey (see, Taymaz and Yılmaz, 2007 and Kılıçaslan et al., 2015), there is no study that examines the impact of different types of intangibles on productivity. The aim of this paper is to contribute to this strand of literature by using the firm level production function approach to estimate the empirical magnitude of the elasticities of capital inputs, comparing tangibles and intangibles, as well as different types of intangibles. This last point is important because, in spite of a large amount of empirical evidence at the level of aggregate intangibles, we still know little about the disaggregated effects of different types of intangibles on productivity as stressed in the above literature.

The empirical analysis is based on the estimation of a Cobb-Douglas production function applied to a panel of Turkish manufacturing firms employing more than 19 workers over the period 2003-2012. A number of alternative estimators have been used in econometric modeling such as dynamic panel data analysis, i.e. Generalized Methods of Moments (GMM) and a semi-parametric estimation method proposed by Olley and Pakes (1996). This paper is organized as follows: The next section introduces the data set used in exploring the impact of tangible and intangible assets on productivity, briefly puts forward the methodology used to calculate conventional and other capital stocks and provides a short descriptive analysis. Section 3 develops the econometric analysis and the next section presents the main empirical findings quantifying the productivity enhancing effects of intangible assets in Turkish manufacturing industry. Finally, Section 5 concludes after a short discussion of the key results from this study and evaluates the policy implications.

2. The data and descriptive analysis

The analysis in this research is based on the Annual Industry and Service Statistics Database (2015) obtained from Turkish Statistical Institute (TURKSTAT). This database covers all enterprises employing more than 19 employees and for the enterprises active in some special classes by full enumeration and a sampling census of the enterprises employing less than 19 employees and provides firm level information on many firm-specific variables. During the years 2002-2008, NACE Rev.1.1 classification was used as a statistical classification of economic activities for Annual Industry and Service Statistics. Since 2009, the classification of enterprises by type of activity has been determined in accordance with the Statistical Classification of Economic Activities in the European Community NACE Rev.2.

In order to prepare the data, we first checked for the consistency of the variables through the years. We found out that the codes for the same variable may change from one year to another. We corrected all those variables that are inconsistent. All monetary series are in Turkish liras and deflated using a 4-digit industry level deflator with 2003 as the base year. The classification of enterprises by type of activity has been determined by NACE Rev.2 for all sectors. The final sample we selected is an unbalanced panel of 23,023 Turkish manufacturing firms employing more than 19 employees over the 2003–2012 period (176,864 observations).

The capital input is defined theoretically as the services of capital goods in value terms. Since data for capital services and the replacement value of fixed assets are not available, we need to use a proxy variable. There are four alternatives: the number of machines installed, total horsepower of installed equipment, depreciation allowances, and book value of fixed assets. In line with Taymaz and Saatçi (1997), we use depreciation allowances to measure the capital stock. Capital stock is constructed by using the perpetual inventory method. The database contains only information on investment. Detailed subcategories of investment are aggregated to tangible investment (lands and buildings; including total construction of residential and non-residential structures, infrastructure, machinery and equipment; including transport, computing and communications equipment) and intangible investment (computer software, purchased patents, intellectual property rights and licenses, and goodwill) and also disaggregation of intangible investment to computer software, patent and goodwill. In addition to this, ICT investment (office and computing equipment and communication equipment and software) and non-ICT investment also aggregated to construct ICT and non-ICT capital stocks[2]. Since the data does not contain information on capital stock in any year we construct initial capital stock series for each firm.

The methodology used in calculating the *capital stock K* is to proxy capital stock of the initial year by using depreciation allowances and adding rent expenses made to capital stock. In this method we used 7.5% as a depreciation rate for tangible capital stock calculations whereas 25% for intangible capital stock calculations[3]. Letting *K*, *i*, and *d* stand for capital, investment and depreciation rate respectively, the capital stock in this methodology is measured as follows:

$$K_{t+1} = K_t + i_{t+1} - d{*}K_{t+1} \quad (1)$$

Note that in the equation above, K_t is the capital stock of year 2003 and is proxied by depreciation allowances. In order to construct separate stocks for *tangible* (K_T) and *intangible* (K_{INT}) capital from investment data, we compute the share of tangible and intangible investment in total investment. The initial capital stock of tangible and intangible series is proxied by shares of depreciation allowances. Given the deflated investments and shares of depreciation allowances for different types of capital, we apply the perpetual inventory method with constant, geometric depreciation to construct the capital stocks for tangible and intangible capital.

2 For a detailed study on disaggregation of tangible, intangible, ICT and non-ICT investments see, Hempell, T. (2005) and Van Reenen et al. (2010)

3 We also used 10% and 15% as the depreciation rates but did not report the empirical findings based on them in here.

In order to examine how and to what extent other intangible capital input factors like investments in patent, design and licenses, goodwill, ICT capital and computer software can explain the variability of firm productivity, we also disaggregated intangible capital to different categories. The above-mentioned methodology has been used for constructing *ICT* (K_{ICT}) and *non-ICT* (K_{NONICT}) *capital stocks*. Moreover, capital stocks for *computer software* (K_{CS}), *patent* (K_P) *and goodwill* (K_G) are also constructed by using shares of depreciation allowances of initial year and then by applying the perpetual inventory method with constant, geometric depreciation given the deflated investments[4].

Table 1 illustrates the number of firms in the sample according to size[5] and technological intensity[6]. About 60 percent of the firms in our sample are small sized enterprises, 32 percent of them are medium-sized enterprises and only 8 percent of them are large-scale enterprises. The share of medium sized firms at the beginning of the analysis period was 55 percent but in 2012 the share of medium sized firms in all manufacturing firms have increased to 64 percent. Low-tech manufacturing firms constituted the largest share in our sample (55%) whereas the share of high-tech manufacturing firms is only 2 percent.

4 The patent investment includes expenses on patent, design and licenses and goodwill investment includes goodwill and organizational expenses.

5 Number of employees is used as the size criterion. Establishments employing fewer than 50 people are classified as ‘‘small-sized enterprise” and establishments employing more than 50 and lower than 250 people are classified as “medium-sized enterprise’’. “Large-scale enterprises” (LSE) employ 250 or more people.

6 Eurostat uses the following aggregation of the manufacturing industry according to technological intensity and based on NACE Rev. 2 at 3-digit level for compiling aggregates related to high-technology, medium-technology and low-technology (1) High-tech: basic pharmaceutical products and pharmaceutical preparations (21); computer, electronic and optical products (26); air and spacecraft and related machinery (30.3) (2) Medium-tech: chemicals and chemical products (20); fabricated metal products, except machinery and equipment (25); electrical equipment (27); machinery and equipment n.e.c. (28); motor vehicles, trailers and semi-trailers (29); other transport equipment (30 -excluding (30.3)); medical and dental instruments and supplies (32.5), reproduction of recorded media (18.2); coke and refined petroleum products (19); rubber and plastic products (22); other non-metallic mineral products (23); basic metals (24); repair and installation of machinery and equipment (33) (3) Low-tech: food products (10); beverages (11); tobacco products (12); textiles (13); wearing apparel (14); leather and related products (15); wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (16); paper and paper products (17); printing and reproduction of recorded (18, excluding 18.2); furniture (31); other manufacturing (32, excluding 32.5) (http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/ Annexes/htec_esms_an3.pdf)

Table 1
Number of Firms

Year	All	19-49	50-249	250+	Low-tech	Medium-tech	High-tech
2003	8081	4421	2914	746	4412	3509	160
2004	10917	6184	3798	935	5880	4816	221
2005	15487	9817	4634	1036	8284	6947	256
2006	17782	11293	5346	1143	9503	7998	281
2007	17899	10782	5868	1249	9541	8084	274
2008	17771	10279	6190	1302	9335	8153	283
2009	16180	9408	5630	1142	8433	7502	245
2010	21454	13606	6563	1285	11368	9791	295
2011	24218	15518	7243	1457	12874	11043	301
2012	27075	17427	8067	1581	14689	12083	303

Source: Annual Industry and Service Statistics Database, TURKSTAT.

Table 2
Proportion of Firms with Respective Intangibles

Year	ICT	Tangible	Intangible	Computer software	Patent	Goodwill
2003	0.66	0.76	0.26	0.20	0.05	0.07
2004	0.66	0.74	0.29	0.24	0.06	0.07
2005	0.65	0.74	0.24	0.17	0.06	0.07
2006	0.71	0.78	0.35	0.15	0.16	0.20
2007	0.67	0.75	0.33	0.14	0.16	0.18
2008	0.64	0.73	0.31	0.13	0.15	0.17
2009	0.67	0.77	0.33	0.14	0.17	0.19
2010	0.71	0.80	0.32	0.12	0.16	0.19
2011	0.73	0.82	0.34	0.13	0.18	0.21
2012	0.71	0.81	0.33	0.13	0.18	0.20

Source: Annual Industry and Service Statistics Database, TURKSTAT.

Table 2 illustrates the importance of investments in intangible assets by measuring the share of firms that have invested in different kind of intangible assets. It turns out that by far not all firms invest in intangibles. For instance, about 70 percent of the firms in our sample report positive investment in ICT and only 31 percent have invested in intangible assets. For both indicators, however, we observe an increase in the last three waves. Around 13 percent report positive expenditures for patent stock. This includes expenditures for external knowledge, design, and licenses. Much more common are investments in goodwill and organizational capital (15%). About 16 percent of the companies invest in capital formation by investing in computer software purchases. Moreover, there is also a shift in intangible investment patterns of firms from computer software expenses to purchased patents, intellectual property rights and licenses.

Table 3

Differences in Firm Productivity by Intangible Assets

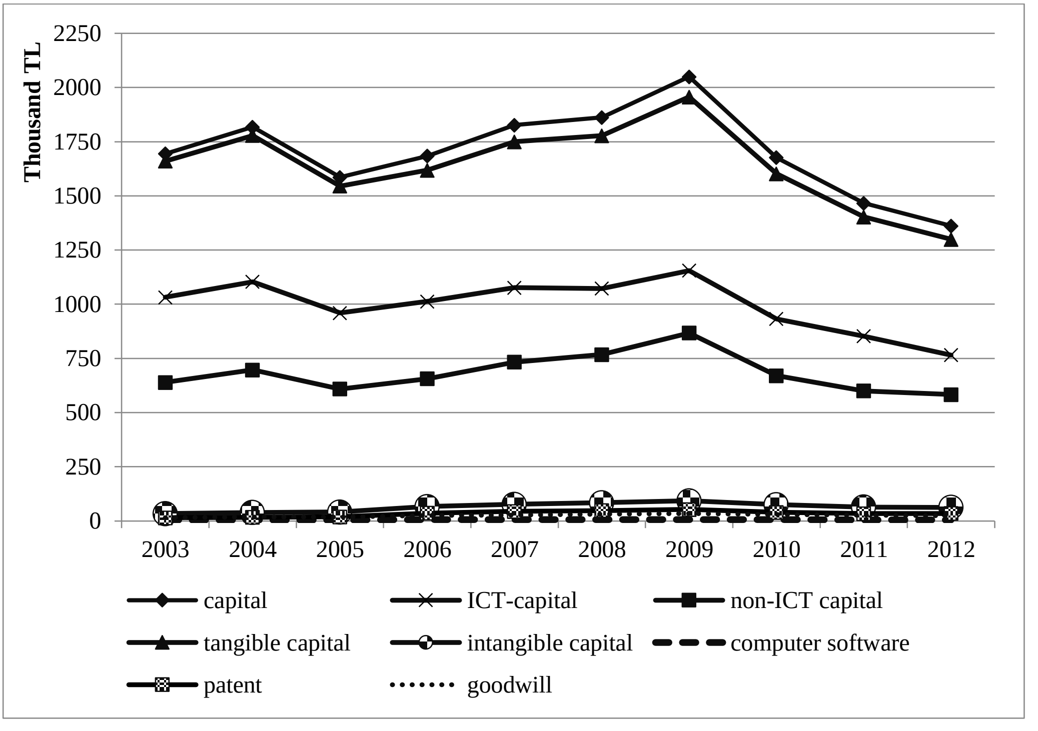
	ICT		Intangible Capital		Computer Software		Patent Stock		Goodwill	
Year	Non-Investors	Investors	Non-Investors	Investors	Non-Investors	Investors	Non-Investors	Investors	Non-Investors	Investors
2003	9.33	9.65	9.40	9.95	9.43	9.99	9.52	9.96	9.38	9.99
2004	9.32	9.70	9.43	9.91	9.46	9.93	9.54	10.00	9.35	10.03
2005	9.20	9.52	9.30	9.75	9.33	9.78	9.38	9.82	9.32	9.80
2006	9.22	9.60	9.33	9.77	9.42	9.90	9.42	9.83	9.25	9.73
2007	9.22	9.59	9.32	9.77	9.40	9.89	9.40	9.82	9.20	9.70
2008	9.24	9.64	9.34	9.84	9.43	9.97	9.43	9.90	8.88	9.77
2009	9.25	9.69	9.39	9.87	9.48	9.95	9.47	9.90	8.81	9.81
2010	9.27	9.63	9.38	9.82	9.47	9.95	9.46	9.88	9.06	9.77
2011	9.26	9.65	9.38	9.86	9.48	9.99	9.46	9.92	9.00	9.78
2012	8.93	9.45	9.14	9.62	9.23	9.76	9.22	9.68	8.22	9.53

Source: Annual Industry and Service Statistics Database, TURKSTAT.

Do firms that invest in intangible assets differ in productivity? The descriptive statistics of Table 3 suggest this. Average labor productivity of firms (in terms of logarithm) that invest in whatever intangible asset, are considerably higher than that of non-investors. We will use two different econometric methods to analyze whether and to what extent this productivity enhancing impact of intangibles holds.

The following three figures depict the constructed capital stock series for the manufacturing sector firms that are classified according to size. The tangible and ICT capital stocks behaved in a similar way through the period 2003 to 2012 for small-sized firms (see Figure 1). We observed a decline in capital stock levels in the first three years of overall period, followed by a rapid increase in the second part of period up to 2009, and stagnation in capital stock levels in the last subperiod (the period 2009 to 2012). This decline is remarkable since tangible capital stock deteriorated and reached a lower value than that of its value in 2003. Moreover, subperiod comparisons by disaggregated capital stocks reveal the largest difference between ICT and non-ICT capital stocks for all subperiods. The share of ICT capital stock in total capital stock is close to 60% for small-sized firms.

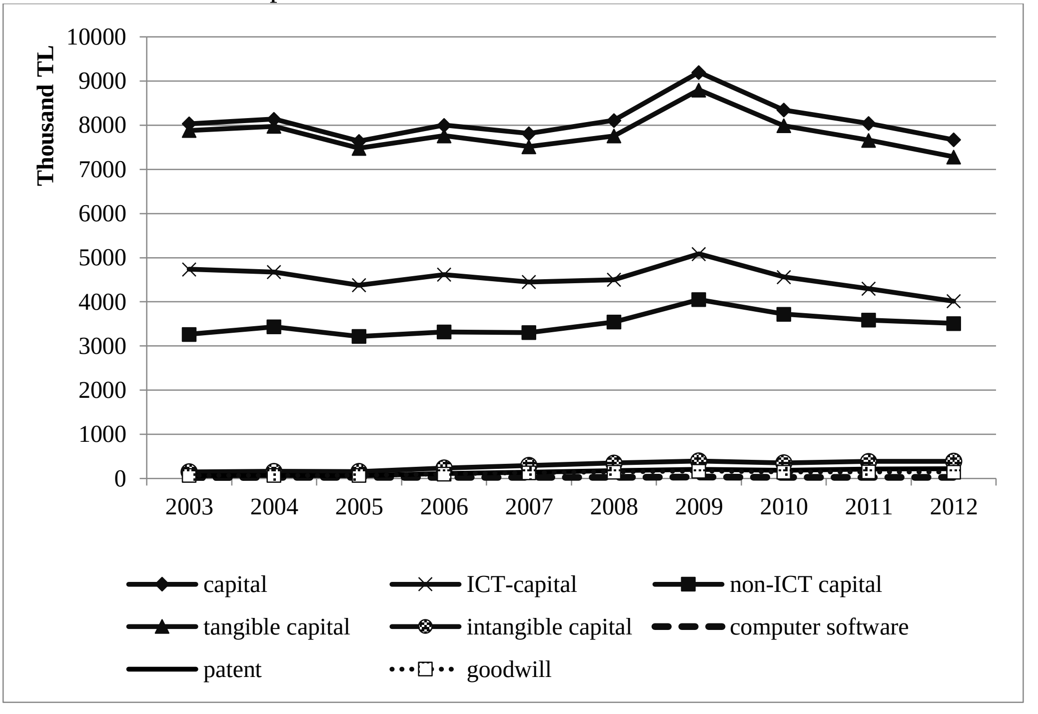
Figure 1
Capital Stock Series for Small-sized Firms



Source: Annual Industry and Service Statistics Database, TURKSTAT.

The disaggregated intangible capital stocks followed an unchanged trend, albeit at a slower pace (see Figure 2). The share of intangibles in total capital stock is just 2 percent but it shows an increasing trend at the end of the period (5% in 2012). Computer software capital constitutes 10% of total intangible capital stock but the share of computer software capital in total intangible capital stock has declined to 7% in 2012. This is replaced by the increase in the share of patent capital stock (as a part of R&D capital). The patent capital stock constitutes 52 percent of total intangible capital stock for small-sized firms.

Figure 2
Capital Stock Series for Medium-sized Firms

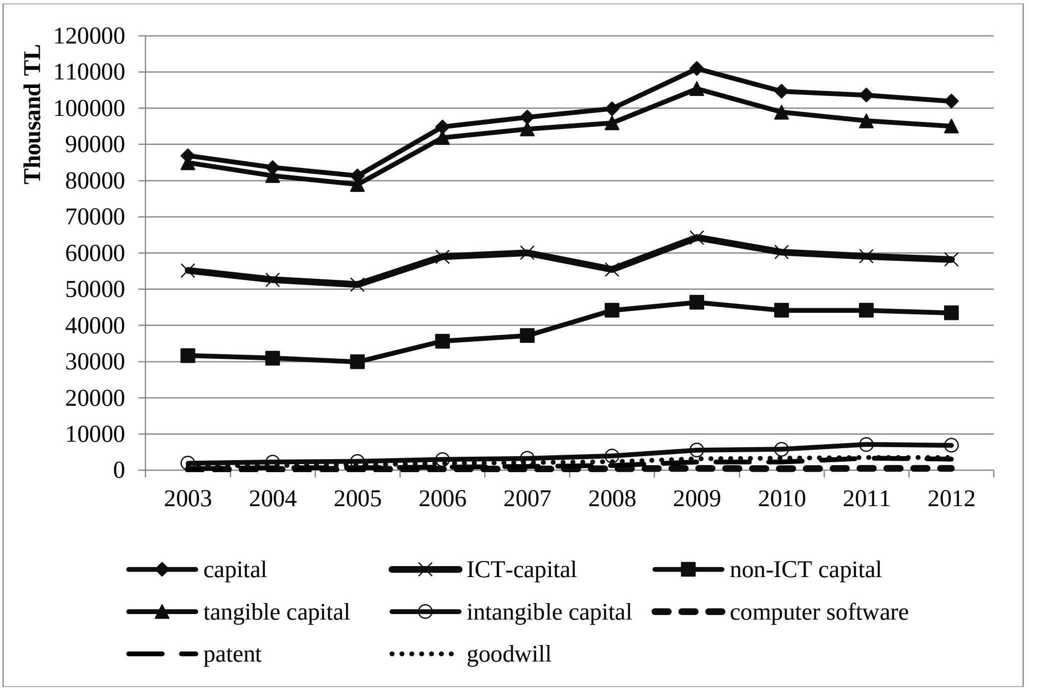


Source: Annual Industry and Service Statistics Database, TURKSTAT.

The tangible and ICT capital stocks behaved in a similar way through the period 2003 to 2012 for medium-sized firms as well (see Figure 2). We observed that subperiod comparisons by disaggregated capital stocks reveal the largest difference between ICT and non-ICT capital stocks for all subperiods although it is smaller compared to that of small-sized firms. The share of ICT capital stock in total capital stock is close to 56% for medium-sized firms.

The disaggregated intangible capital stocks followed an unchanged and lower trend (see Figure 2). The share of intangibles in total capital stock for medium-sized firms is just 2 percent but it shows an increasing trend at the end of the period (5% in 2013). Computer software capital stock constitutes 14% of total intangible capital stock in 2003 but it has declined to 7% in 2012. This is replaced by the increase in the share of patent capital stock (as a part of R&D capital). The patent capital stock constitutes 49 percent of total intangible capital stock for medium-sized firms.

Figure 3
Capital Stock Series for Large-scale Firms

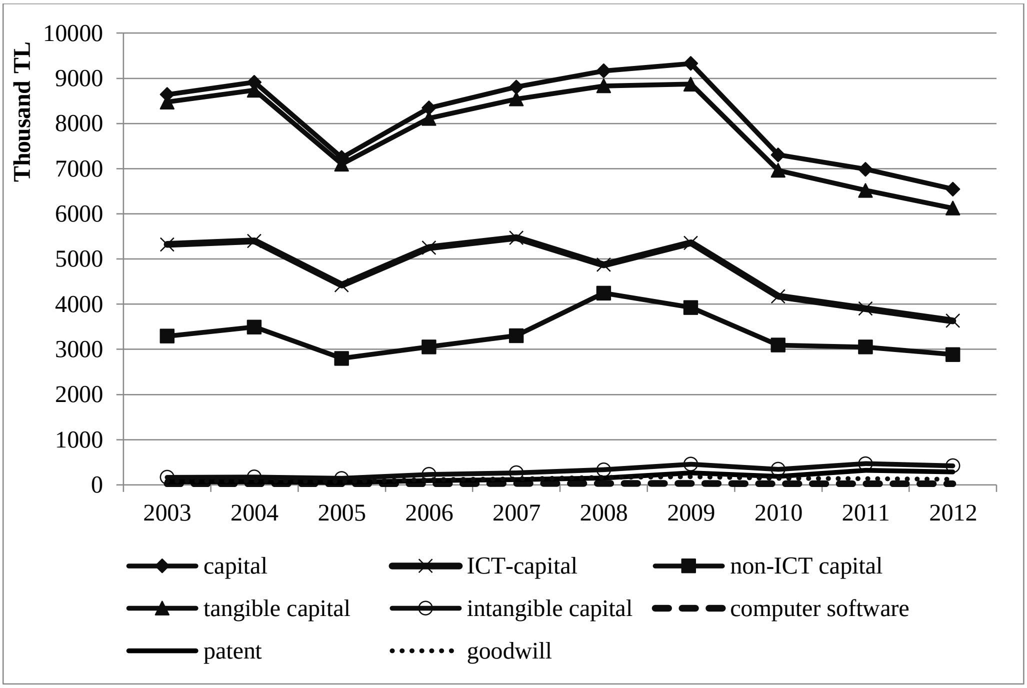


Source: Annual Industry and Service Statistics Database, TURKSTAT.

Figure 3 depicts different capital stocks through the period 2003 to 2012 for large-scale firms. We observed a decline in capital stock levels in the first three years of overall period, followed by a rapid increase in the second part of period up to 2009, and stagnation in capital stock levels in the last subperiod (the period 2009 to 2012). This decline is not as dramatic as the one notified in small-sized firms since deteriorated tangible capital stock is higher than that of its value in 2003. The difference between ICT and non-ICT capital stocks gets smaller as the share of ICT capital stock in total capital stock is close to 64% in 2003 whereas it deteriorates to 57% in 2012.

The disaggregated intangible capital stocks followed an increasing trend especially after 2009 for large-scale firms (see Figure 3). The share of intangibles in total capital stock for large-scale firms is 7% in 2012. Computer software capital stock constitutes about 10% of total intangible capital stock in the overall period. The share of patent capital stock (as a part of innovative capital) increases from 24% in 2003 to 45% in 2013. Moreover, the goodwill capital stock (that includes a part of organizational expenses) constitutes a high share of 59 percent in intangible capital stock.

Figure 4
Capital Stock Series for Low-tech Firms



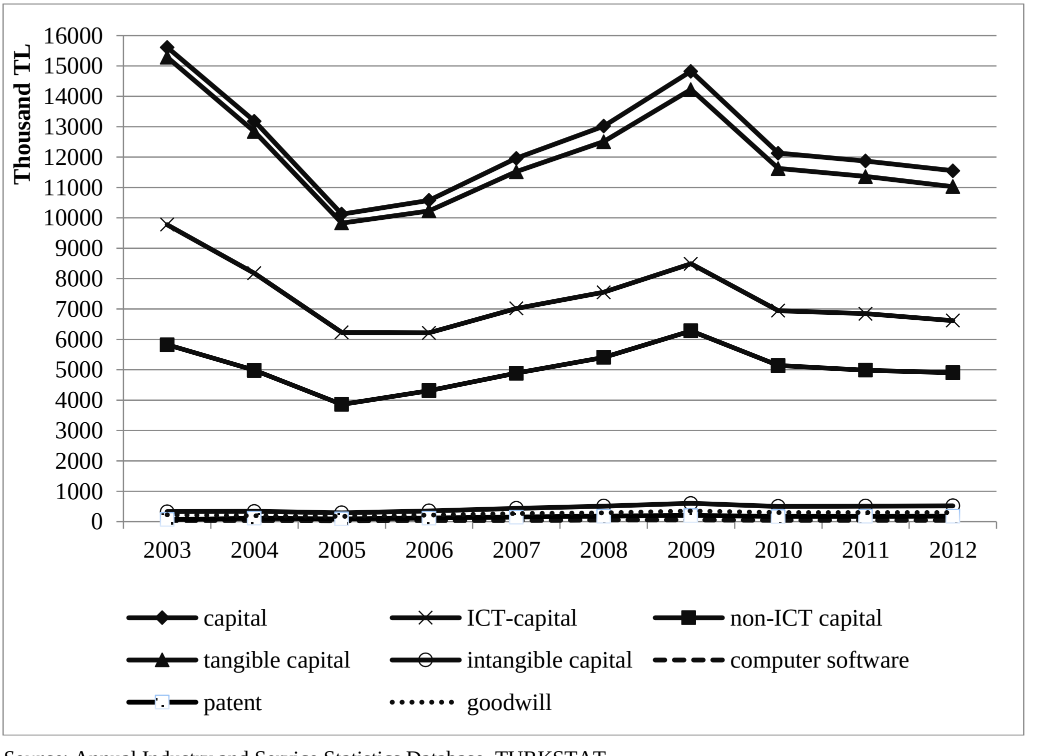
Source: Annual Industry and Service Statistics Database, TURKSTAT.

Figure 4 and Figure 5 depict the constructed capital stock series for the manufacturing sector firms that are classified based on technological intensity. The tangible and total capital stock series move closely for low and medium-tech firms. Capital stock levels in the first three years of overall period follow the same pattern and declines sharply in 2005. This is followed by a rapid increase in the second part of the period up to 2009 reaching back to its original level in 2003. The last subperiod depicts stagnation in capital stock levels and this decline is remarkable since tangible capital stock deteriorated to a lower value than that of its value in 2005. Moreover, subperiod comparisons by disaggregated capital stocks reveal the largest difference between ICT and non-ICT capital stocks for all subperiods. The share of ICT capital in total capital stock is 60% for both low and medium-tech firms.

The disaggregated intangible capital stocks followed an unchanged trend, albeit at a slower pace (see Figure 4 and Figure 5). The share of intangibles in total capital stock is just 2 percent but it shows an increasing trend at the end of the period (6% in 2012) for both low and medium-tech firms. Computer software capital stock constitutes 10% of total intangible capital stock but the share of computer software stock in total intangible capital stock has declined from 12% in 2003 to 5% in 2012. The share of patent capital stock in low-tech firms has increased from 39% to 67% whereas this increase in the share of patent capital stock is from 21% to 35% for medium-tech firms.

Figure 5

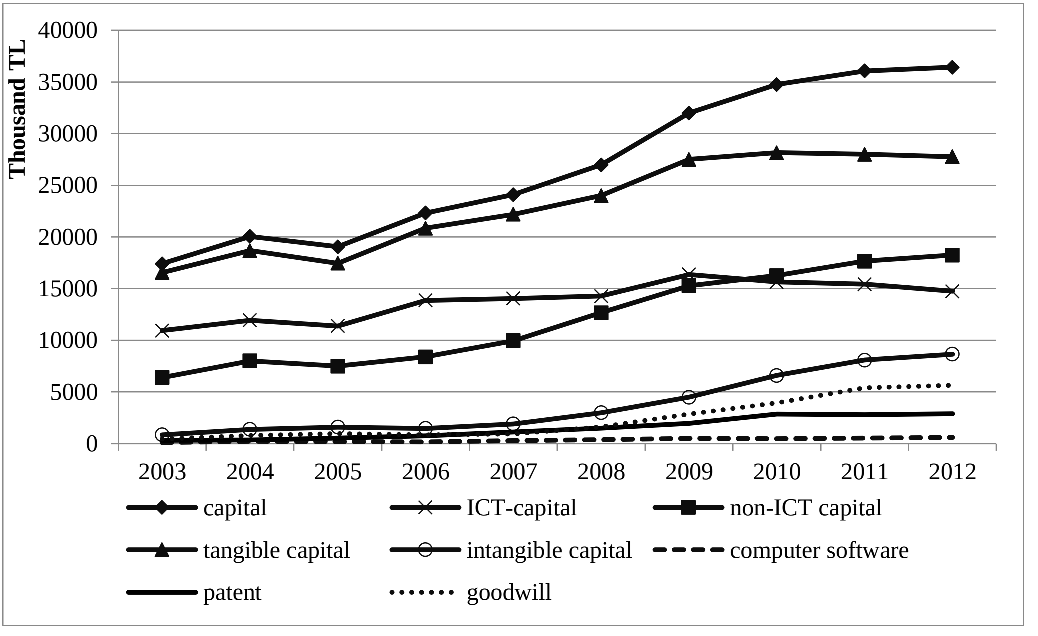
Capital Stock Series for Medium-tech Firms



Source: Annual Industry and Service Statistics Database, TURKSTAT.

Figure 6 depicts the constructed capital stock series for high-tech firms. Different than all other firms classified according to size and also from low and medium-tech firms, the only persisting increase in capital stock series is observed for high-tech firms. Even if the increase in capital stock levels has continued after 2009 with only exception of ICT capital stock. The share of ICT capital stock in total capital stock has decreased from 60% to 40% in 2012 for high-tech firms.

Figure 6
Capital Stock Series for High-tech Firms



Source: Annual Industry and Service Statistics Database, TURKSTAT.

The disaggregated intangible capital stocks followed an increasing trend as well since 2007 for high-tech firms (see Figure 6). The share of intangibles in total capital stock shows an increasing trend at the end of the period (24% in 2012). Computer software capital constitutes 11% of total intangible capital stock whereas the share of patent capital stock for high-tech firms is 41 percent. The share of goodwill capital stock (like large-scale firms) has increased from 52% to 65% in 2012 for high-tech firms.

3. Empirical implementation

Productivity as a measure of the efficiency of production may be defined as a ratio of output to inputs used in the production. Labor productivity defined as the ratio of output/value added to the number of workers of hours worked is said to be the most commonly used partial measure of productivity. Widespread utilization of labor productivity is simply due to the fact that it is easy to measure. Total factor productivity (TFP), also called multi-factor productivity, on the other hand, is measure of productivity that accounts for the output increase not caused by the factors of production. TFP cannot be measured directly. Instead it is a residual, often called the *Solow residual*, which accounts for effects in total output not caused by inputs.

TFP measurement helps to disentangle the direct growth contributions of labor, capital, intermediate inputs and technology. However, one has to be aware that measured TFP growth is not necessarily caused by technological change: other non-technology factors will also be picked up by the residual. Such factors include adjustment costs, scale and cyclical effects, pure changes in efficiency and measurement errors (OECD, 2001: 24 and Carlaw and Lipsey, 2003: 458). It was the important contribution of Jorgenson and Griliches (1967) to point out that TFP growth would not measure the full contribution of new technology but it would only measure the gains in output that were over and above their development costs through the super-normal profits and externalities associated with such change.

There are many methodologies available for productivity estimation that needs to be classified according to different criteria. The first distinction one should keep in mind when approaching this field is between methodologies used in macro studies, i.e. methods concerned with aggregate (countries/regions/industry) productivity, and methodologies used in micro studies, aimed at measuring individual (firm/plant) productivity (Del Gatto et al., 2011: 953). The interest in estimating individual (firm/plant) productivity gained importance due to the development of a theoretical literature in which firms are assumed to be heterogeneous in terms of productivity, and the increasing availability of micro-level data. The main focus of this strand of literature is on the relationship between the productivity distribution of firms and the integration process (see for example, Bernard et al., 2003; Melitz and Ottaviano, 2008). The empirical literature dwells around understanding firm-level differences in performance, as well as in studying the determinants of these differences (see for example, Clerides et al., 1998; Pavcnik, 2002; Del Gatto et al., 2008).

Studies in this field also rely on semi-parametric methods, based on proxy variables. These methods consider the main problems associated with estimating productivity at the firm level, namely simultaneity, selectivity and price dispersion. The key points of semi-parametric methods are (*i*) the identification of a proxy variable, which is a function of the observed firm level TFP, and (*ii*) the definition of the conditions under which this function can be inverted in order to express TFP as a function of the proxy variable itself (Del Gatto et al., 2011:954). For example, Levinsohn and Petrin (2003) suggest using intermediate goods as a function of TFP and capital. This function is invertible provided that, with given capital, the utilization of intermediate goods increases with TFP growth. Olley and Pakes (1996) suggest using investment instead as a proxy in order to address the potential simultaneity bias in the production function estimates.

In order to check for the productivity enhancing effects of intangible assets on output growth, we follow the line of research mentioned in the literature that have used a production function approach in general and a Cobb-Douglas production function in particular as their theoretical framework. Suppose the production function takes the form of Cobb-Douglas and given as follows:

$$Q_{it} = A_{it} L_{it}^{\beta_L} K_{it}^{\beta_K} \tag{2}$$

where i indicates firms and t years. Q is value added and A encapsulates unmeasured components such as R&D stocks and other intangibles, technology levels and marginal efficiency, input quality and effort (Del Gatto et al., 2011:959). K (later on decomposed as *tangible capital* (K_T) and *intangible capital* (K_{INT}) *stocks*; *ICT* (K_{ICT}) and *non-ICT* (K_{NONICT}) *capital stocks*; *intangible capital* (K_{INT}) *stocks* as *computer software* (K_{CS}), *patent* (K_P) *and goodwill* (K_G) *capital stocks*) is stock of capital, and L is labor units.

$$K_{it} = K_{it}^{T} + K_{it}^{INT} \tag{3}$$

If we take the logs of the variables in the above equation and treat the capital input as intangible capital (K^{INT}) and tangible capital (K^{T}), keeping the same notation, Equation (2) can be written as follows (O'Mahony and Vecchi, 2005 and Van Beveren, 2012):

$$q_{it} = \beta_0 + \beta_l l_{it} + \beta_k^T k_{it}^T + \beta_k^T k_{it}^l + \varepsilon_{it} \tag{4}$$

Assuming that TFP is firm specific, we can estimate Equation (4) by using fixed-effects. However, there are many problems with estimating econometric relationships such as the production function in Equation (4). First, if there is unobserved heterogeneity, the intangible capital coefficient may be picking up the effect of an omitted factor such as managerial ability. Unobserved firm-specific factors positively correlated with intangible capital, like firms with innovative ability are likely to invest more in R&D or ICT, will cause the coefficient, β_k^I , to be biased upward (Van Reenen et al., 2010:30).

The techniques for dealing with these issues relate to instrument variables that are usually based on lagged values of the dependent and explanatory variables (see for a detailed discussion, Blundell and Bond, 1998 and 2000; Olley and Pakes, 1996). We will thereby use Generalized Methods of Moments (GMM) method to deal with the endogeneity arising from the input decisions of firms. Specifically, after first-differencing the production function, the lagged levels of inputs can be used as instruments for changes in the inputs (Wooldridge, 2009).

The formal specification of the GMM model to be estimated will be as follows:

$$q_{it} = \beta_0 + \beta_q q_{i,t-1} + \beta_l I_{it} + \beta_k^T k_{it}^T + \beta_k^{INT} k_{it}^{INT} + \varepsilon_{it} \tag{5}$$

The estimated value of β_k^{INT} will give the impact of intangible capital on output (value added) growth in Equation (5). This coefficient indeed is the elasticity of output with respect to intangible capital. Moreover, the regression controls are represented by year dummies that are supposed to capture the effects of macroeconomic phenomena, which vary over time but not across firms. The year dummies in Equation (5) may also account for technological change.

Olley and Pakes (1996) method, on the other hand, accounts for both endogeneity of inputs and outputs in the production function and selection bias due to firm entry and exit (which is likely to be correlated with productivity), by using two-stage procedures where unobserved TFP is "proxied" by another state variable(s) such as investment. In essence, Olley and Pakes replace Equation (5) with

$$q_{it} = \beta_0 + \beta_l I_{it} + \beta_k^T k_{it}^T + \beta_k^{INT} k_{it}^{INT} + \omega_t + n_t \tag{6}$$

where q_t is output, l_t is the labor input and k^T is the tangible capital stock and, k^{INT} is intangible capital stock. The plant-specific error term, $\boldsymbol{\varepsilon_t}$ is composed of a plant-specific productivity component, $\boldsymbol{\omega_t}$, and an i.i.d. component, $\boldsymbol{\eta_t}$. The latter term has no impact on the plant's decisions. The productivity term, $\boldsymbol{\omega_t}$, which is not observed by the econometrician, is known by the plant manager and this term impacts the plant's decision rules (Özler and Yılmaz, 2009: 345). Consistent parameter estimates of the coefficients on the variable input (labor) can then be obtained using a semi-parametric estimator by modeling $\boldsymbol{\varphi_t}$ as a polynomial series expansion in capital and investment as in Olley and Pakes model (for details see, Del Gatto et al., 2011).

4. Econometric results: Effects of intangibles on productivity

The descriptive statistics of the estimation sample are summarized in Table A1 in Appendix. The majority of firms in the reference sample are small and medium–sized firms with a mean of 105 employees. About 7% of the sample consists of large-scale firms employing on average 686 employees. Table A1 shows that the estimation sample reflects low and medium-tech dominated structure of the Turkish manufacturing firms. Only 2% of the sample consists of high-tech firms.

Table 4
Effect of Intangibles on Firm-level Productivity: Olley and Pakes (1996) Estimation Method

Dependent variable: value added				
	(1)	(2)	(3)	(4)
Capital	0.166***			
	(0.0218)			
Labor	0.795***	0.792***	0.778***	0.729***
	(0.0015)	(0.0067)	(0.0102)	(0.0216)
ICT capital		0.0699***		
		(0.0108)		
Non-ICT capital		0.0891***		
		(0.0053)		
Tangible capital			0.130***	0.144***
			(0.0113)	(0.0116)
Intangible capital			0.0342***	
			(0.0020)	
Computer software				0.0475***
				(0.0057)
Patent				0.0127***
				(0.0031)
Goodwill				0.0084***
				(0.0018)
Observations	138141	138141	138141	138141

Standard errors in parentheses.
Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$
All variables are log-transformed and all regressions include constant and time dummies.
Source: Annual Industry and Service Statistics Database, TURKSTAT.

The empirical analysis in based on the estimation of Equation (5) and (6) that is discussed in the previous section. In Table 4, we present the estimation results for the aggregate sample obtained by applying the Olley and Pakes (1996) estimation method[7]. Column (1) depicts the estimates of a traditional production function using the traditional input factors. Conventional capital and labor turn out to be highly significant with an estimated output elasticity of roughly 0.17 and 0.80. We then gradually enrich the specification by including various components of intangible assets. In Column (2), we include ICT capital and non-ICT capital

[7] We have used a user-developed command, *opreg*, that has recently been made available in STATA, due to Yasar et al. (2008).

additionally. ICT capital turns out to be highly significant with an estimated output elasticity of roughly 0.07. The output elasticity of non-ICT capital (0.09) is higher than that of ICT capital (0.07) indicating that non-ICT capital (0.068) has a higher marginal productivity than that of ICT capital (0.037)[8].

In specification 3 we additionally account for tangible and intangible capital. The estimated output elasticity of tangible capital is roughly 0.13 that is a higher value than that of intangible capital (0.03). However, intangible capital has higher marginal productivity (0.231) than that of tangible capital (0.039). We further augment the production function by alternatively including computer software, patent and goodwill capital in specification (4). Computer software, patent and goodwill capital turn out to be highly significant with an estimated output elasticity of 0.05, 0.013 and 0.008 respectively. Moreover, the marginal productivity for computer software, patent and goodwill capital is 3.64, 0.16 and 0.14. These marginal productivities are higher than that of tangible capital's calculated marginal productivity (0.042). These findings underpin the need to include all tangible as well as intangible inputs in order to properly estimate production functions. In other words, even when controlling for a comprehensive set of intangible assets, we find especially strong positive and a higher productivity effects for computer software capital compared to intangible capital in the third specification.

Table 5 represents the estimation results for different size classifications obtained by applying the Olley and Pakes (1996) estimation method. Conventional capital and labor turn out to be highly significant with an estimated output elasticity of roughly 0.15 and 0.80 for three different size classes. The estimated elasticity of capital tends to increase, as firms get larger in size. When we enrich the specification by including ICT and non-ICT capital into the model, ICT capital turns out to be highly significant with an estimated output elasticity of roughly 0.05 for small-sized firms, 0.08 for medium-sized firms and 0.06 for large-scale firms. The highest output elasticity of ICT capital is attained for medium-sized firms showing the important impact of ICT usage in manufacturing sector.

The estimated output elasticity of tangible capital is higher than the output elasticity of intangible capital for all size classes. The highest output elasticity of intangible capital (0.05) is attained for large-scale firms. Moreover, intangible capital stock has higher marginal productivity compared to that of tangible capital for all size classes. The highest marginal productivity is attained for large-scale firms (6.72). We further augment the production function by alternatively including computer software, patent and goodwill capital in specification (4). Computer

8 The marginal physical product (MPP) of capital is equal to the derivative of output with respect to the capital variable, whereas the estimated coefficient is equal to the derivative of log output with respect to log capital variable. Therefore, the marginal productivity (MPP) is equal to multiplication of output elasticity with the inverse ratio of ICT capital in output (for a detailed discussion see, Hempell (2005)).

software capital turns out to be positive and significant for all size classes with estimated output elasticity of 0.03, 0.05 and 0.07 for small, medium and large-sized firms. The highest output elasticity of computer software capital is attained for large-scale firms. The output elasticity of patent capital is only significant for small-sized firms whereas the only significant elasticity for goodwill capital is obtained for medium-sized firms.

Regarding the marginal productivity of different intangible capital inputs, computer software capital has higher marginal productivity than tangible capital for all size classes. The magnitude of marginal productivity intensifies as firm size increases. The marginal productivity of computer software capital is 3.51, 4.28 and 5.77 for small, medium and large-sized firms. The only higher marginal productivity of patent capital (0.26) compared to tangible capital (0.04) is obtained for small-sized firms. These findings highlight the positive role played by computer software capital as a knowledge asset in determining firms' productive performance. Moreover, patent capital as a form of innovative capital is important for small-sized firms in order to build up their own knowledge capacity that is mainly based on the external acquisition of intangible assets.

We also evaluate the effect of intangibles on firm level productivity for different technological intensity (see Table 6). The estimated elasticity of conventional capital tends to increase, as technological intensity of firm increases. When we enrich the specification by including ICT and non-ICT capital into the model, ICT capital turns out to be significant with an estimated output elasticity of roughly 0.05 for low-tech firms and 0.07 for medium-tech firms. The highest output elasticity of ICT capital is attained for medium-tech firms. The estimated output elasticity of tangible capital is higher than the output elasticity of intangible capital for all types of technological classifications. The highest output elasticity of intangible capital (0.06) is attained for high-tech firms. Moreover, intangible capital stock has higher marginal productivity compared to that of tangible capital regardless of technology intensity of firms. The calculated marginal productivity for low, medium and high-tech firms are 0.20, 0.28 and 0.25, indicating the highest contribution of intangible capital on productivity to be attained for medium-tech firms.

When we include computer software, patent and goodwill capital in the production function, computer software capital turns out to be positive and significant for low and medium-tech firms with estimated output elasticity of 0.03 and 0.05 respectively. The highest output elasticity of computer software capital is attained for medium-tech firms. The output elasticity of patent capital is only significant for low-tech firms whereas the different types of intangibles do not have any statistically significant effect on high-tech firms.

Table 5
Effect of Intangibles on Firm-level Productivity According to Size: Olley and Pakes (1996) Estimation Method

Dependent variable: value added	(1)			(2)			(3)			(4)		
	19-49	50-249	250+	19-49	50-249	250+	19-49	50-249	250+	19-49	50-249	250+
Capital	0.157***	0.155***	0.163***									
	(0.0192)	(0.0146)	(0.0517)									
Labor	0.891***	0.810***	0.733***	0.898***	0.808***	0.751***	0.892***	0.794***	0.724***	0.837***	0.786***	0.613***
	(0.0224)	(0.0206)	(0.0587)	(0.0170)	(0.0197)	(0.0490)	(0.0070)	(0.0329)	(0.0225)	(0.0396)	(0.0106)	(0.0237)
ICT capital				0.0552***	0.0756**	0.0613***						
				(0.0019)	(0.0311)	(0.0034)						
Non-ICT capital				0.0872***	0.0910***	0.111***						
				(0.0067)	(0.0068)	(0.0107)						
Tangible capital							0.117***	0.111***	0.145***	0.109***	0.231***	0.0552
							(0.0207)	(0.0211)	(0.0073)	(0.0264)	(0.0757)	(0.156)
Intangible capital							0.0256***	0.0429***	0.0458***			
							(0.0041)	(0.0093)	(0.0084)			
Computer software										0.0324***	0.0495***	0.0733**
										(0.0017)	(0.0023)	(0.0360)
Patent										0.0170**	0.0085	0.0191
										(0.0068)	(0.0088)	(0.0141)
Goodwill										0.00879	0.00501**	0.0145
										(0.0090)	(0.0023)	(0.0201)
Observations	79819	47390	10932	79819	47390	10932	79819	47390	10932	79819	47390	10932

Standard errors in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1
All variables are log-transformed and all regressions include constant and time dummies.
Source: Annual Industry and Service Statistics Database, TURKSTAT.

Table 6

Effect of Intangibles on Firm-level Productivity According to Technological Intensity: Olley and Pakes (1996) estimation method

Dependent variable: value added

	(1)			(2)			(3)			(4)		
	Low-tech	Medium-tech	High- tech	Low-tech	Medium-tech	High- tech	Low-tech	Medium-tech	High- tech	Low-tech	Medium-tech	High- tech
Capital	0.150***	0.174***	0.300**									
	(0.0116)	(0.0072)	(0.150)									
Labor	0.817***	0.794***	0.832***	0.816***	0.791***	0.817***	0.803***	0.782***	0.803***	0.775***	0.729***	0.739***
	(0.0118)	(0.0120)	(0.0130)	(0.0019)	(0.0107)	(0.0339)	(0.0084)	(0.0237)	(0.0753)	(0.0134)	(0.0063)	(0.0185)
ICT capital				0.0625***	0.0711***	0.0493						
				(0.0165)	(0.0152)	(0.0933)						
Non-ICT capital				0.0739***	0.100***	0.125***						
				(0.0021)	(0.0036)	(0.0087)						
Tangible capital							0.106***	0.157***	0.233**	0.126***	0.160***	0.270***
							(0.0257)	(0.0021)	(0.118)	(0.0186)	(0.0446)	(0.0811)
Intangible capital							0.0290***	0.0331***	0.0660*			
							(0.0031)	(0.0007)	(0.0365)			
Computer software										0.0329***	0.0513***	-0.0013
										(0.0045)	(0.0057)	(0.0178)
Patent										0.0195***	-0.0011	0.0481
										(0.0027)	(0.0078)	(0.0322)
Goodwill										0.0011	0.0099	0.0299
										(0.0034)	(0.0065)	(0.0400)
Observations	71919	64007	2215	71919	64007	2215	71919	64007	2215	71919	64007	2215

Standard errors in parentheses.
Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$
All variables are log-transformed and all regressions include constant and time dummies.
Source: Annual Industry and Service Statistics Database, TURKSTAT.

Regarding the marginal productivity of different intangible capital inputs, computer software capital has higher marginal productivity than that of tangible capital for low and medium-tech firms. The magnitude of marginal productivity of computer software capital is higher for medium-tech firms (4.61) compared to low-tech firms (2.92). The only higher marginal productivity of patent capital (0.23) compared to tangible capital (0.03) is obtained for low-tech firms. The positive role played by computer software capital as a knowledge asset in determining firms' productive performance increases with technological intensity of manufacturing firms.

Table 7

Effect of Intangibles on Firm-level Productivity: GMM Estimation Method

Dependent variable: value added	(1)	(2)	(3)	(4)
Lagged value added	0.0505***	0.0622***	0.0521***	0.0568*
	(0.0155)	(0.0156)	(0.0179)	(0.0325)
Labor	0.773***	0.742***	0.772***	0.674***
	(0.0251)	(0.0246)	(0.0301)	(0.0387)
Capital	0.0765***			
	(0.0087)			
ICT capital		0.0393***		
		(0.0090)		
Non-ICT capital		0.0427***		
		(0.0071)		
Tangible capital			0.0624***	0.0775***
			(0.0096)	(0.0156)
Intangible capital			0.0173***	
			(0.0035)	
Computer software				0.0138*
				(0.0083)
Patent				0.0102*
				(0.0059)
Goodwill				0.0085
				(0.0067)
Constant	8.761***	8.754***	8.893***	9.116***
	(0.195)	(0.196)	(0.227)	(0.416)
Observations	100641	93096	76014	27416
Number of firms	23023	21327	15809	5108
Wald Statistics (df)	3175.91[9]	3187.22[10]	2689.80[10]	1341.19[12]
Sargan (p-values)	392.15	364.3	319.59	158.48
	(0.000)	(0.000)	(0.000)	(0.000)
Residuals (p–values)				
AR(1)	-16.935	-16.562	-14.881	-8.9634
	(0.000)	(0.000)	(0.000)	(0.000)
AR(2)	-1.5615	-1.6671	-1.3734	-0.2488
	(0.0118)	(0.0955)	(0.1696)	(0.8035)

WC-robust standard errors of Windmeijer in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1
All variables are log-transformed and all regressions include year dummies.
Source: Annual Industry and Service Statistics Database, TURKSTAT.

Alternatively, Table 7 shows the impact of disaggregated intangibles on productivity by using GMM two-step estimation method[9]. In this estimation, instruments for differenced equation include GMM type instrument that is the lagged value of value added and standard instruments that are capital and labor inputs. Regarding the tests for overidentification and for autocorrelation, the output of Sargan test of overidentifying restrictions for the above models present strong evidence against the null hypothesis that the overidentifying restrictions are valid. However, Baum et al. (2003) indicates that the validity of inference on Sargan test diminishes if we use of heteroskedasticity-consistent or "robust" standard errors and statistics. The estimated models also present no significant evidence of serial correlation in the first-differenced errors at order 2.

The estimation results show that conventional capital and labor turn out to be highly significant with an estimated output elasticity of roughly 0.07 and 0.77. In Column (2) we include additionally ICT and non-ICT capital to model specification. ICT capital turns out to be significant with an estimated output elasticity of roughly 0.04. The output elasticity of ICT and non-ICT capital is close to each other (and as well marginal productivity's) indicating that ICT capital is at least as productive as non-ICT capital.

In specification 3, the estimated output elasticity of tangible capital is roughly 0.06 that is a higher value than that of intangible capital (0.02). The intangible capital has higher marginal productivity (0.13) than that of tangible capital (0.02). When different types of intangibles are included in the production function, computer software and patent capital turn out to be significant with an estimated output elasticity of 0.013 and 0.010 respectively. Moreover, the marginal productivity of patent (0.16) and computer software capital (1.26) are higher compared to marginal productivity of tangible capital (0.02) indicating the significance of knowledge assets.

Table 8 shows the impact of disaggregated intangibles on productivity by different size classes. Note, all twelve models are deemed sufficient in terms of tests for autocorrelation (AR(1) and AR(2) test statistics). When we enrich the specification by including ICT and non-ICT capital into the model, ICT capital turns out to be highly significant with an estimated output elasticity of roughly 0.03 for small-sized firms and 0.05 for medium-sized firms. Different than the estimated

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9 The Olley and Pakes (OP) estimators can also be estimated in a single step, by stacking up all the relevant moments. The main advantage of a one step approach is in computing the standard errors. Moreover, OP method allow for first order process (not just a linear AR(1)). But a dynamic panel approach can allow for fixed effects in addition to the AR(1) process indicating more persistence in the productivity shock, while OP method can not. Another important reason for using dynamic panel approach is that it does not require scalar unobservable or monotonicity condition (for a detailed discussion, see Van Beveren (2012)).

models without size classification, the inclusion of disaggregated capital input in the production function does not provide any statistically significant results for large-scale firms. The marginal productivity of ICT capital (0.027) is the same as the marginal productivity of non-ICT capital. This finding indicates that ICT capital is at least as productive as non-ICT capital for medium-sized firms showing the notable impact of ICT usage in manufacturing sector.

The estimated output elasticity of tangible capital is higher than the output elasticity of intangible capital for small and medium sized firms. The highest output elasticity of intangible capital (0.017) is attained for small-sized firms. Moreover, intangible capital has higher marginal productivity than that of tangible capital both in small and medium-sized firms (0.17 for small-sized and 0.13 for medium-sized firms). When we augment the production function by including computer software, patent and goodwill capital in specification (4), the only significant output elasticity is obtained for patent capital. These medium-sized firms demonstrate very high returns to innovative capital in form of patent capital (with a marginal productivity of 0.192) to build up their own knowledge capacity.

Table 9 shows the impact of disaggregated intangibles on productivity by technological intensity. All models are found to be sufficient in terms of tests for autocorrelation (AR(1) and AR(2) test statistics) except for high-tech specification. The estimation results show that ICT capital turns out to be significant with an estimated output elasticity of roughly 0.02 for low-tech firms, 0.045 for medium-tech firms and 0.065 for high-tech firms. The output elasticity of ICT increases as the technology intensity of firms increase.

The estimated output elasticity of tangible capital is higher than the estimated elasticity of intangible capital, especially in medium-tech firms. However, intangible capital has higher marginal productivity (0.218) compared to tangible capital (0.024) for medium-tech firms. The productivity enhancing impact of intangible capital is also higher than that of tangible capital in low-tech firms but the magnitude of the contribution is smaller (0.07) than that of medium-tech firms. When different types of intangibles are included in the production function, only significant estimation results are attained for medium-tech firms. The computer software capital turns out to be significant with an estimated output elasticity of 0.03 and also with high marginal productivity (2.64). Thus, intangibles especially in the form of computer software capital, contributes to productivity remarkably for medium-tech manufacturing firms.

Table 8

Effect of Intangibles on Firm-level Productivity According to Size: GMM Estimation Method

	(1)			(2)			(3)			(4)		
	19-49	50-249	250+	19-49	50-249	250+	19-49	50-249	250+	19-49	50-249	250+
Lagged value added	0.0350**	0.0390*	0.0944	0.0426**	0.0456**	0.0286	0.0372*	0.0413*	0.0774	0.0243	0.000781	0.0483
	(0.0169)	(0.0221)	(0.0951)	(0.0173)	(0.0227)	(0.105)	(0.0207)	(0.0232)	(0.0981)	(0.0385)	(0.0342)	(0.146)
Labor	0.739***	0.730***	0.571***	0.731***	0.697***	0.570***	0.690***	0.722***	0.581***	0.735***	0.780***	0.523***
	(0.0396)	(0.0291)	(0.0611)	(0.0389)	(0.0283)	(0.0626)	(0.0511)	(0.0342)	(0.0594)	(0.0523)	(0.0568)	(0.0430)
Capital	0.0836***	0.0732***	0.0265									
	(0.0112)	(0.0158)	(0.0217)									
ICT capital				0.0346***	0.0493**	0.0398						
				(0.0075)	(0.0198)	(0.0304)						
Non-ICT capital				0.0465***	0.0401***	-0.0026						
				(0.0076)	(0.0130)	(0.0487)						
Tangible capital							0.0629***	0.0663***	0.0268	0.0738***	0.0759***	0.0260
							(0.0102)	(0.0187)	(0.0209)	(0.0156)	(0.0249)	(0.0310)
Intangible capital							0.0198***	0.0173***	0.00925			
							(0.0041)	(0.0046)	(0.0097)			
Computer software										0.0044	0.0057	0.009
										(0.0144)	(0.0060)	(0.0137)
Patent										0.0122	0.0127**	0.0000
										(0.0116)	(0.0064)	(0.0124)
Goodwill										0.0189	0.0088	-0.0078
										(0.0119)	(0.0063)	(0.0105)
Constant	8.812***	9.294***	10.883***	8.888***	9.203***	11.81***	9.167***	9.296***	11.014***	9.064***	9.516***	12.10***
	(0.271)	(0.273)	(1.268)	(0.261)	(0.285)	(1.420)	(0.316)	(0.303)	(1.324)	(0.550)	(0.438)	(1.845)
Observations	52696	38825	9120	47605	36643	8848	35437	31978	8599	9694	12496	5226
Number of firms	16165	10469	1989	14615	9988	1948	10196	8119	1823	2705	2968	1030
Wald Statistics (df)	897.50[9]	2409.4[9]	759.11[9]	872.14[10]	2378.17[10]	752.80[10]	556.02[10]	2087.1[10]	775.85[10]	394.56[12]	823.84[12]	481.10[12]
Sargan (p-values)	211.59	154.77	59.878	205.10	144.63	57.37	184.61	126.54	58.625	112.60	91.986	63.100
	(0.000)	(0.000)	(0.005)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.005)	(0.000)	(0.000)	(0.002)
Residuals (p–values)												
AR(1)	-12.712	-9.7909	-3.8387	-12.295	-9.3509	-3.1527	-10.841	-9.2091	-3.537	-7.7755	-5.5975	-2.0322
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.042)
AR(2)	-1.2928	0.3084	-0.9298	-1.9436	0.5443	-1.2308	-1.6899	0.6887	-1.1011	-0.1182	0.7275	-0.9266
	(0.1961)	(0.7577)	(0.3525)	(0.0519)	(0.5862)	(0.2184)	(0.0911)	(0.4910)	(0.2709)	(0.9059)	(0.4669)	(0.3541)

WC-robust standard errors of Windmeijer in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed and all regressions include year dummies.

Source: Annual Industry and Service Statistics Database, TURKSTAT.

Table 9

Effect of Intangibles on Firm-level Productivity According to Technological Intensity: GMM Estimation Method

	(1)			(2)			(3)			(4)		
	Low-tech	Medium-tech	High-tech	Low-tech	Medium-tech	High- tech	Low-tech	Medium-tech	High- tech	Low-tech	Medium-tech	High- tech
Lagged value added	0.0380**	0.0612***	0.341***	0.0544***	0.0625**	0.333***	0.0404*	0.0480*	0.370***	0.0284	0.0613	0.326**
	(0.0189)	(0.0231)	(0.0805)	(0.0194)	(0.0243)	(0.0881)	(0.0223)	(0.0272)	(0.0755)	(0.0384)	(0.0468)	(0.128)
Labor	0.755***	0.759***	0.802***	0.719***	0.745***	0.814***	0.740***	0.750***	0.791***	0.697***	0.605***	1.023**
	(0.0337)	(0.0325)	(0.146)	(0.0315)	(0.0347)	(0.157)	(0.0394)	(0.0398)	(0.148)	(0.0491)	(0.0486)	(0.492)
Capital	0.0642***	0.0780***	0.0394									
	(0.0128)	(0.0119)	(0.0330)									
ICT capital				0.0259*	0.0453***	0.0652***						
				(0.0148)	(0.0094)	(0.0252)						
Non-ICT capital				0.0375***	0.0553***	0.0331						
				(0.0095)	(0.0109)	(0.0301)						
Tangible capital							0.0480***	0.0740***	0.0132	0.0657***	0.0778***	-0.0297
							(0.0145)	(0.0125)	(0.0216)	(0.0207)	(0.0141)	(0.0503)
Intangible capital							0.0116***	0.0258***	0.0143			
							(0.0039)	(0.0056)	(0.0243)			
Pc Software										0.0065	0.0294**	-0.0193
										(0.0060)	(0.0139)	(0.0601)
Patent										0.0120	0.0052	0.0383
										(0.0087)	(0.0076)	(0.0305)
Goodwill										0.0070	0.0102	-0.0130
										(0.0080)	(0.0094)	(0.0662)
Constant	9.076***	8.737***	5.786***	9.106***	8.573***	5.735***	9.334***	8.888***	5.674***	9.487***	9.375***	6.013***
	(0.271)	(0.269)	(1.043)	(0.265)	(0.282)	(1.147)	(0.317)	(0.316)	(1.005)	(0.533)	(0.570)	(1.727)
Observations	53093	45968	1580	49124	42500	1481	39249	35338	1427	13837	12810	769
Number of firms	12330	10675	365	11341	9961	349	8276	7482	318	2640	2404	155
Wald Statistics (df)	1216.8[9]	2157.5[9]	249.30[9]	1282.14[10]	2098.38[10]	209.32[10]	1069.8[10]	1778.8[10]	250.27[10]	604.18[12]	831.61[12]	145.33[12]
Sargan (p-values)	202.89	233.31	50.677	194.52	210.13	49.4857	162.98	185.32	43.719	95.111	95.301	44.852
	(0.000)	(0.000)	(0.042)	(0.000)	(0.000)	(0.0532)	(0.003)	(0.000)	(0.148)	(0.000)	(0.000)	(0.122)
Residuals (p–values)												
AR(1)	-11.996	-12.507	-5.5327	-11.893	-11.672	-5.2413	-10.475	-10.75	-5.6304	-6.5148	-6.5518	-3.6674
	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)
AR(2)	0.1649	-2.0264	1.2765	0.5641	-2.4034	1.1816	0.3404	-2.055	1.4048	1.4744	-1.459	0.9207
	(0.8690)	(0.0427)	(0.2018)	(0.5727)	(0.0162)	(0.2374)	(0.7335)	(0.0399)	(0.1601)	(0.1404)	(0.1446)	(0.3572)

WC-robust standard errors of Windmeijer in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed and all regressions include year dummies.

Source: Annual Industry and Service Statistics Database, TURKSTAT.

5. Conclusion

In contrast to many recent papers investigating the contribution of intangible assets to productivity growth at the macro level, this paper takes a firm-level perspective. It contributes to the literature by simultaneously investigating productivity effects of a comprehensive set of intangible assets following the conceptual framework of Corrado et al. (2009). In particular, our econometric approach accounts for ICT capital and intangible capital and also the disaggregation of intangible capital into three components, namely computer software, patent and goodwill capital. This disaggregation of intangible capital is important since expenses on patent stock and computer software constitute innovative capital and they are external sources to build up the internal knowledge capacity of firms.

Using an unbalanced panel data for Turkish manufacturing firms employing more than 19 employees, we can draw the following conclusions for the period 2003-2012. First, disaggregating capital into intangible and tangible is essential to evaluate empirical magnitude of elasticites of different capital inputs and their marginal productivities. The contribution of including intangible capital into production function is considerably high and this impact does not change in regards to firm size or technological intensity. On the other hand, even when controlling for a comprehensive set of intangible assets, we find especially strong positive productivity effects for computer software capital. Focusing on intangible components, the highest marginal productivity is that of computer software capital. This result does not change by grouping the firms into different size classes and technology intensities. Moreover, the marginal productivity of patent capital is higher than that of tangible capital for small-sized firms and for low-tech firms.

These findings indicate that the productivity of Turkish manufacturing firms is mainly driven by patent royalties and part of ICT expenses on computer software. The marginal contribution of patent capital is relatively considerable compared to other components for small firms and also for firms having low technology intensity. This highlights the importance of policies that are designed to stimulate the accumulation of intangible capital stocks external to the firms. Second, firms that increase their expenditure for different intangible assets experienced on average an increase in productivity though the effect is rather small in magnitude. As firms get larger and improve in technological intensity, the magnitude of marginal productivity increases for computer software capital. And finally, investing in ICT capital has a beneficial effect on firm's productivity. The application of a suited GMM estimator yields evidence for significant productivity effects of intangible assets. However, these are substantially smaller than those suggested by Olley and Pakes (1996) estimates. These findings underpin the need to include all tangible as well as intangible capital inputs in order to properly estimate production functions.

Apart from these findings discussed, measurement errors in the explanatory variables may lead to an underestimation of the corresponding elasticities. As stated by Hempell (2005), this problem is severe in specifications using first differences or within estimation and is particularly important for the case of ICT capital. Even though ICT investments have increased substantially over the last years, the share of ICT equipment and computer software in total capital is still very small. This makes it difficult to distinguish the output contributions of ICT from statistical noise.

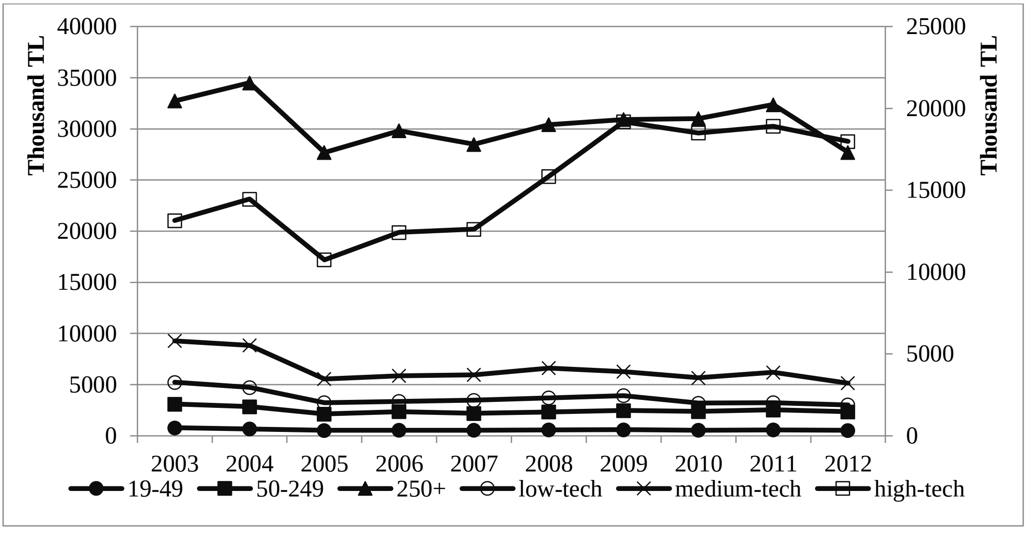
Even if the firm–level approach can offer various insights that are much more difficult to obtain from aggregate data, the productivity of ICT may vary between firms. If some firms are better enabled than others to use new technologies successfully, some complementary factors like skills, innovations and organizational assets are important. Even though the investigation of complementary factors is beyond the scope of this paper, finding suited methodological approaches to assess these questions should further be elaborated.

From an economic point of view, the findings of this paper highlight the need of investigating particular firm characteristics and strategies in more detail. The results from the preferred Olley and Pakes (1996) estimation imply that a one–percent increase in ICT raises output by about 0.06 percent. Hempell (2005) argues that these apparent returns are likely to be due to unobserved complementary expenses such as adjustment cost, innovation efforts, training or other intangible assets, but they may also reflect differences between firms in their ability to exploit the potential benefits of ICT. The evaluation of adjustment costs and relevant firm characteristics and strategies that are related to ICT use are important issues for future research on the productivity and welfare impacts of the “Information Economy”.

Appendix

Figure A1

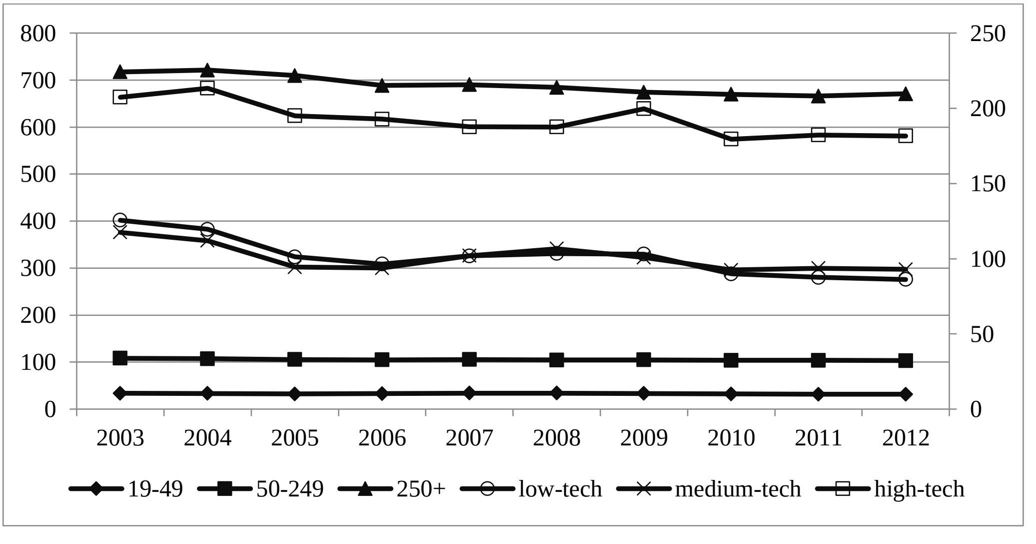
Value added Structure of Firms According to Size and Technological Intensity



Note: Technology based classification of firms is depicted on the secondary axis.
Source: Annual Industry and Service Statistics Database, TURKSTAT.

Figure A2

Employment Structure of Firms According to Size and Technological Intensity



Note: Technology based classification of firms is depicted on the secondary axis.
Source: Annual Industry and Service Statistics Database, TURKSTAT.

Table A1
Detailed Statistics for the Estimated Samples (value added and capital stocks are measured in 1000 TL)

	Mean	Std. Dev.	Min	Max		Mean	Std. Dev.	Min	Max
Full sample (176864 obs. for 23023 firms)					*(19-49) sample (108735 obs. for 16165 firms)*				
Value added	3166	21100	0	1490000	Value added	567	1014	0	94700
Employees	100	290	20	17229	Employees	33	9	20	49
Capital	10800	88800	0	8830000	Capital	1805	4872	0	758000
ICT-capital	6047	54300	0	7300000	ICT-capital	988	2720	0	138000
Non-ICT capital	4556	44400	0	8160000	Non-ICT capital	745	2145	0	224000
Tangible capital	10300	84700	0	8790000	Tangible capital	1733	4714	0	735000
Intangible capital	664	13200	0	2280000	Intangible capital	114	517	0	46200
Computer software	89	1005	0	91900	Computer software	16	122	0	14100
Patent	444	12400	0	2270000	Patent	106	529	0	42400
Goodwill	466	8124	0	1120000	Goodwill	61	279	0	25600
Low-tech sample (94319 obs. for 12330 firms)					*(50-249) sample (56253 obs. for 10469 firms)*				
Value added	2209	11600	0	895000	Value added	2431	3860	0	138000
Employees	98	267	20	17229	Employees	105	50	50	249
Capital	8440	69000	0	8830000	Capital	8332	20500	0	912000
ICT-capital	4722	44000	0	7300000	ICT-capital	4608	11800	0	441000
Non-ICT capital	3553	37000	0	8160000	Non-ICT capital	3713	10800	0	676000
Tangible capital	8092	65700	0	8790000	Tangible capital	8013	20100	0	910000
Intangible capital	502	13600	0	2280000	Intangible capital	399	1660	0	68700
Computer software	60	536	0	40400	Computer software	51	253	0	14300
Patent	442	16500	0	2270000	Patent	298	1302	0	52100
Goodwill	260	3834	0	330000	Goodwill	232	1262	0	68700
Medium-tech sample (79926 obs. for 10675 firms)					*(249+) sample (11876 obs. for 1989 firms)*				
Value added	3889	26900	0	1490000	Value added	30400	75700	35	1490000
Employees	98	307	20	15330	Employees	686	924	250	17229
Capital	13000	107000	0	6270000	Capital	99200	319000	0	8830000
ICT-capital	7340	64600	0	3470000	ICT-capital	58900	200000	0	7300000
Non-ICT capital	5444	51100	0	3170000	Non-ICT capital	40900	161000	0	8160000
Tangible capital	12500	103000	0	5980000	Tangible capital	94600	304000	0	8790000
Intangible capital	677	7829	0	440000	Intangible capital	4895	42800	0	2280000
Computer software	98	1150	0	91900	Computer software	487	2766	0	91900
Patent	347	3832	0	219000	Patent	2325	35900	0	2270000
Goodwill	562	6867	0	373000	Goodwill	3462	25300	0	1120000

Table A1 (cont'd)

High-tech sample (2619 obs. for 365 firms)				
Value added	15600	53000	2	860000
Employees	191	461	20	5937
Capital	28900	101000	0	1830000
ICT-capital	14500	46700	0	533000
Non-ICT capital	13400	63200	0	1600000
Tangible capital	24600	77500	0	806000
Intangible capital	4810	50100	0	1460000
Computer software	545	3243	0	65300
Patent	2523	18000	0	394000
Goodwill	3788	42700	0	1120000

Source: Annual Industry and Service Statistics Database, TURKSTAT.

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Özet

Türkiye'de maddi olmayan varlıkların imalat sanayii firmalarının üretkenliği üzerindeki etkisi

Gelişmiş ülkelerin deneyimlerine dayanarak, Ar-Ge harcamaları, imtiyaz, patent, lisans ve marka gibi haklardan oluşan maddi olmayan varlıkların, firmaların performansını etkileyen bilginin önemli bileşenlerini içerdikleri söylenebilir. Bu çalışmanın amacı, Türk imalat sanayii firmaları için sermaye girdilerinin firma üretkenliği üzerine etkilerini incelemektir. Çalışmada 2003-2012 yılları arasında, maddi ve maddi olmayan varlıkların, aynı zamanda muhtelif maddi olmayan varlıkların firmaların üretkenliği üzerindeki etkisi karşılaştırılmaktadır. Cobb-Douglas üretim fonksiyonuna ait esneklik katsayısı tahminleri, Genelleştirilmiş Momentler Yöntemi (GMM) ve Olley ve Pakes (1996) tarafından geliştirilen yarı parametrik bir tahmin yöntemi olmak üzere iki farklı ekonometrik yönteme dayanmaktadır. Yapılan analizlere göre maddi olmayan varlıklara yaptıkları yatırımları arttıran firmalarda azımsanmayacak üretkenlik artışları görülmektedir. Buna ek olarak, farklı maddi olmayan varlıkların üretime katkısı incelendiğinde, özellikle bilgisayar yazılımı ve patent hakları sermayesinin üretkenliğe güçlü katkısı öne çıkmaktadır.

Anahtar kelimeler: Üretkenlik, maddi ve maddi olamayan sermaye, imalat sanayii, Türkiye.

JEL kodları: D24, L60, O14.